CLAIMS

1. A multilayer holographic recording and reproducing method for holographically recording information on a multilayer holographic recording medium including a number of deposited holographic recording layers in each of which interference fringes can be formed by projecting an object beam and a reference beam that are split from a laser beam and for reproducing the recorded information by projecting a laser beam for reproduction, , the method comprising:

a process of recording the information by fixing a projection condition of one of the object beam and the reference beam and modulating the other for each of the holographic recording layers so that the holographic recording layers each have a different Bragg's condition; and

a process of projecting the laser beam for reproduction onto the deposited holographic recording layers with the same projection condition as the fixed projection condition of the one of the object beam and the reference beam to generate a diffraction beam in an upper holographic recording layer and to make a transmitted 0-th order diffraction beam be projected onto a lower holographic layer one by one, thereby simultaneously or individually reproducing pieces of information from diffraction beams generated in the respective holographic recording layers by the projected beams.

2. The multilayer holographic recording and reproducing method according to claim 1, wherein;

during the holographic recording, the information is recorded by fixing a projection condition of the reference beam and modulating the object beam for each of the holographic recording layers; and

the laser beam for reproduction having the same projection condition as that of the reference beam is projected onto the deposited holographic recording layers, the diffraction beams generated in the respective holographic recording layers by the projected beams are detected by two-dimensional photodetectors a number of which is equal to that of the holographic recording layers, and the pieces of information are reproduced from light-detecting signals of the two-dimensional photodetectors.

3. The multilayer holographic recording and reproducing method according to claim 1, wherein

the information is recorded by shift-multiplex recording for each of the holographic recording layers over an entire surface thereof.

4. The multilayer holographic recording and reproducing method according to claim 2, wherein

the information is recorded by shift-multiplex recording for each of the holographic recording layers over an entire surface thereof.

5. The multilayer holographic recording and reproducing method according to any one of claims 1 to 4, wherein

an angle of the other of the object beam and the reference beam is modulated for each of the holographic recording layers during the holographic recording.

6. The multilayer holographic recording and reproducing method according to claim 5, wherein

during the reproduction of information, a beam diameter of the laser beam for reproduction is enlarged, and the laser beam for reproduction is modulated by spatial light modulation to make a part of the laser beam for reproduction incident on the holographic recording layers from a different position within the enlarged beam diameter.

7. The multilayer holographic recording and reproducing method according to claim 5, wherein

during the reproduction of information, the laser beam for reproduction is reflected by a rotating mirror and a concave mirror to be incident on the holographic recording layers.

8. The multilayer holographic recording and reproducing method according to claim 1, wherein

during the holographic recording of information, the information is recorded by modulating an intensity of the object beam in accordance with the information to be recorded and modulating the reference beam by phase spatial light

modulation for each of the holographic recording layers such that the interference fringes in each of the holographic recording layers have a phase code pattern different from those in the other holographic recording layers; and

during the reproduction of information, the laser beam for reproduction is modulated by phase spatial light modulation for each of the holographic recording layers from which the information is to be reproduced, so as to have a corresponding phase code pattern, and is then projected onto the holographic recording layers.

9. A multilayer holographic recording and reproducing method for holographically recording information on a multilayer holographic recording medium including a number of deposited holographic recording layers in each of which interference fringes can be formed by projecting an object beam and a reference beam that are split from a laser beam, and for reproducing the recorded information, the method comprising:

recording the information by modulating an intensity of the object beam in accordance with the information to be recorded, modulating an incident angle of the object beam for each of the holographic recording layers, and modulating the reference beam by phase spatial light modulation in accordance with an address to be assigned such that each of the holographic recording layers has a phase code pattern that is

different for each address; and

during the reproduction of information, modulating the laser beam for reproduction by phase spatial light modulation with the same projection condition as that of the reference beam to have the phase code pattern, and projecting the modulated laser beam onto the holographic recording layers.

10. A holographic recording and reproducing apparatus for recording information on a multilayer holographic recording medium including a number of deposited holographic recording layers in each of which interference fringes can be formed by projecting an object beam and a reference beam from a laser beam source and for reproducing the recorded information by projecting a laser beam for reproduction, the apparatus comprising:

an object optical system and a reference optical system for directing the object beam and the reference beam to the multilayer holographic recording medium, respectively;

a reproducing laser optical system for projecting the laser beam for reproduction onto the deposited holographic recording layers; and

two-dimensional photodetectors for reproducing pieces of information from diffraction beams generated in the respective holographic recording layers by the laser beams for reproduction, a number of the two-dimensional photodetectors being equal to that of the diffraction beams, wherein

a projection condition of a laser beam in one of the object optical system and the reference optical system is fixed and a projection condition of a laser beam in the other is modulated for each of the holographic recording layers to record information on each of the holographic recording layers with a different Bragg's condition, and the reproducing laser optical system has the same projection condition as the fixed projection condition.

11. The multilayer holographic recording and reproducing apparatus according to claim 10, wherein

the reference optical system is configured to fix a projection condition of the reference beam, the object optical system includes an object beam modulator for modulating the object beam for each of the holographic recording layers, the reproducing laser optical system is configured to make the laser beam for reproduction be projected onto the deposited holographic recording layers with the same projection condition as that of the reference beam, and the two-dimensional photodetectors are configured to separately detect diffraction beams generated in the respective holographic recording layers by the projected beams.

12. The multilayer holographic recording and reproducing apparatus according to claim 10 or 11, wherein

the object optical system and the reference optical system are configured to record the information by shift-

multiplex recording for each of the holographic recording layers over an entire surface thereof.

13. The multilayer holographic recording and reproducing apparatus according to claim 10 or 11, wherein

the other of the object optical system and the reference optical system has an angle modulator for modulating an angle of the other of the object beam and the reference beam for each of the holographic recording layers during the holographic recording.

14. The multilayer holographic recording and reproducing apparatus according to claim 13, comprising: a beam expander for enlarging a beam diameter of the laser beam for reproduction during the reproduction of information; and a spatial light modulator for modulating the laser beam for reproduction having the enlarged beam diameter by spatial light modulation to make a part of the laser beam for reproduction incident on the holographic recording layers from a different position within the enlarged beam diameter.

15. The multilayer holographic recording and reproducing apparatus according to claim 13, comprising an angle modulator for a laser beam for reproduction that reflects the laser beam for reproduction by a rotating mirror and a concave mirror to make the laser beam for reproduction incident on the holographic recording layers during the reproduction of information.

16. The multilayer holographic recording and reproducing apparatus according to claim 10, wherein

the object optical system includes an amplitude spatial light modulator for modulating an intensity of the object beam in accordance with the information to be recorded during the holographic recording of information, and the reference optical system includes a phase spatial light modulator for modulating the reference beam for each of the holographic recording layers by phase spatial light modulation to make interference fringes in the respective holographic recording layers have a different phase code pattern from each other, and

the reproducing laser optical system includes a phase spatial light modulator for a laser beam for reproduction that modulates the laser beam for reproduction by phase spatial light modulation for each of the holographic recording layers from which the information is to be reproduced during the reproduction of information such that the laser beam for reproduction has a corresponding phase code pattern.

17. A multilayer holographic recording and reproducing apparatus for recording information on a multilayer holographic recording medium including a number of deposited holographic recording layers in each of which interference fringes can be formed by projecting an object beam and a reference beam from a laser beam source and for reproducing

the recorded information by projecting a laser beam for reproduction, the apparatus comprising:

an object optical system and a reference optical system for directing the object beam and the reference beam to the multilayer holographic recording medium, respectively;

a reproducing laser optical system for projecting the laser beam for reproduction onto the deposited holographic recording layers; and

two-dimensional photodetectors for reproducing pieces of information from diffraction beams generated in the respective holographic recording layers by the laser beams for reproduction, a number of the two-dimensional photodetectors being equal to that of the diffraction beams, wherein

the object optical system includes an angle modulator for an object beam that modulates an intensity of the object beam in accordance with information to be recorded and modulates an incident angle of the object beam for each of the holographic recording layers, the reference optical system includes a phase spatial light modulator for modulating the reference beam by phase spatial light modulation in accordance with an address to be assigned to make each holographic recording layer have a phase code pattern that is different for each address, and the reproducing laser optical system includes a phase spatial light modulator for a laser beam for reproduction that modulates the laser beam for reproduction by

phase spatial light modulation to make the laser beam for reproduction have the phase code pattern during the reproduction of information.

18. A holographic memory reproducing apparatus for reproducing recorded information by projecting a laser beam for reproduction from a reproducing laser optical system onto a multilayer holographic recording medium, the multilayer holographic recording medium including a number of deposited holographic recording layers, the information being recorded by fixing a projection condition of one of an object beam and a reference beam from a laser beam source and modulating a projection condition of the other thereof for each of the holographic recording layers to make a Bragg's condition different for each of the holographic recording layers, the holographic memory reproducing apparatus comprising two-dimensional photodetectors for reproducing pieces of information from diffraction beams generated in the respective holographic recording layers by the laser beams for reproduction, a number of the two-dimensional photodetectors being equal to that of the diffraction beams, wherein

the reproducing laser optical system has the same projection condition as the fixed projection condition.

19. The multilayer holographic memory reproducing apparatus according to claim 18, wherein

the reproducing laser optical system is configured to

make the laser beam for reproduction be projected onto the deposited holographic recording layers under the same projection condition as that of the reference beam, and the two-dimensional photodetectors are configured to separately detect the diffraction beams generated in the respective holographic recording layers by the projected beams.

20. The multilayer holographic memory reproducing apparatus according to claim 18 or 19, wherein

the information is recorded by shift-multiplex recording for each of the holographic recording layers in the holographic recording medium over an entire surface thereof.

21. The multilayer holographic memory reproducing apparatus according to claim 18 or 19, wherein

the information on the multilayer holographic recording medium is recorded by angle multiplex recording in which an angle of the other of the object beam and the reference beam is modulated for each of the holographic recording layers, and the reproducing laser optical system includes: a beam expander for enlarging a beam diameter of the laser beam for reproduction; and a spatial light modulator for modulating the laser beam for reproduction having the enlarged beam diameter by spatial light modulation to make a part of the laser beam for reproduction incident on the holographic recording layers from a different position within the enlarged beam diameter.

22. The multilayer holographic memory reproducing

apparatus according to claim 18 or 19, comprising an angle modulator for a laser beam for reproduction that reflects the laser beam for reproduction by a rotating mirror and a concave mirror to make the laser beam for reproduction incident on the holographic recording layers.

23. The multilayer holographic memory reproducing apparatus according to claim 18, wherein

the information is recorded on the multilayer holographic recording medium by modulating the reference beam by phase spatial light modulation for each of the holographic recording layers to make the interference fringes have a different phase code pattern, and

the reproducing laser optical system includes a phase spatial light modulator for a laser beam for reproduction that modulates the laser beam for reproduction by phase spatial light modulation for each of the holographic recording layers from which the information is to be reproduced during the reproduction of information such that the laser beam for reproduction has a corresponding phase code pattern.

24. A multilayer holographic memory reproducing apparatus for reproducing recorded information by projecting a laser beam for reproduction onto a multilayer holographic recording medium, the multilayer holographic recording medium including a number of deposited holographic recording layers in each of which interference fringes can be formed by projecting an

object beam and a reference beam from a laser beam source, the information being recorded on the multilayer holographic recording medium by modulating an intensity of the object beam in accordance with information to be recorded, modulating an incident angle of the object beam for each of the holographic recording layers, and modulating the reference beam by phase spatial light modulation in accordance with an address to be assigned to make the holographic recording layers have a phase code pattern that is different for each address, the apparatus comprising:

a reproducing laser optical system for projecting the laser beam for reproduction onto the deposited holographic recording layers; and

two-dimensional photodetectors for reproducing pieces of information from diffraction beams generated in the respective holographic recording layers by the laser beams for reproduction, a number of the two-dimensional photodetectors being equal to that of the diffraction beams, wherein

the reproducing laser optical system includes a phase spatial light modulator for a laser beam for reproduction that modulates the laser beam for reproduction by phase spatial light modulation to make the laser beam for reproduction have the phase code pattern during the reproduction of information.

25. A multilayer holographic recording medium comprising a number of deposited holographic recording layers in each of

which interference fringes generated by projecting an object beam and a reference beam are formed, wherein

information is recorded on the respective holographic recording layers by fixing a projection condition of one of the object beam and the reference beam and modulating a projection condition of the other for each of the holographic recording layers to make a Bragg's condition different for each of the holographic recording layers.

26. The multilayer holographic recording medium according to claim 25, wherein

the information is recorded by shift-multiplex recording for each of the holographic recording layers over an entire surface thereof.

27. The multilayer holographic recording medium according to claim 25 or 26, wherein

the information is recorded by angle multiplex recording in which angular modulation is performed for each of the holographic recording layers.

28. The multilayer holographic recording medium according to claim 25, wherein

the information is recorded for each of the holographic recording layers to make the interference fringes therein have a phase code pattern that is different for each of the holographic recording layers.

29. A multilayer holographic recording medium comprising

a number of deposited holographic recording layers in each of which interference fringes generated by projecting an object beam and a reference beam are formed, wherein

information is recorded on the respective holographic recording layers by angle multiplex recording at different angles between the holographic recording layers, and is recorded to have a phase code pattern that is different for each address in the same holographic recording layer.

30. A manufacturing method of a multilayer holographic recording medium, the method comprising, in order to deposit a predetermined number of holographic recording layers for each of which shift-multiplex recording is performed, sequentially repeating the steps of:

forming a holographic recording layer on a substrate;

projecting an object beam and a reference beam onto the holographic recording layer to perform shift-multiplex recording over an entire surface of the holographic recording layer;

forming a next holographic recording layer on the holographic recording layer; and

projecting an object beam and a reference beam onto the next holographic recording layer to perform shift-multiplex recording over an entire surface of the next holographic recording layer, wherein

the object beam and the reference beam are projected

while a projection condition of one of the object beam and the reference beam is fixed and a projection condition of the other is modulated for each of the holographic recording layers to record information with Bragg's conditions different between the respective holographic recording layers.

31. The manufacturing method of a holographic recording medium according to claim 30, further comprising the step of,

after shift-multiplex recording is performed for the holographic recording layer and before the next holographic recording layer is formed, performing post-exposure of the holographic recording layer for which shift-multiplex recording is performed to completely consume a residual photosensitive component.

32. The manufacturing method of a holographic recording medium according to claim 31, wherein

the post-exposure of the holographic recording layer is performed by using incoherent light.

33. The manufacturing method of a holographic recording medium according to claim 30, 31, or 32, further comprising the step of forming a spacer layer between the respective holographic recording layers, for suppressing optical interference between the respective holographic recording layers and compensating for flatness, parallelism, and mechanical strength of the respective holographic recording layers.

34. The manufacturing method of a multilayer holographic recording medium according to claim 30, 31, or 32, wherein a predetermined number of holographic recording layers for which shift-multiplex recording and phase-code-multiplex recording are performed are deposited by sequentially repeating the steps of:

forming the holographic recording layer on the substrate;

projecting the reference beam to which a phase code pattern different for each address is provided and the object beam onto the holographic recording layer to achieve shift-multiplex recording over an entire surface of the holographic recording layer;

forming the next holographic recording layer on the holographic recording layer; and

projecting the object beam having an incident angle modulated and the reference beam to which a phase code pattern different for each address is provided onto the next holographic recording layer to achieve shift-multiplex recording over an entire surface of the next holographic recording layer.

35. The manufacturing method of a multilayer holographic recording medium according to claim 33 wherein a predetermined number of holographic recording layers for which shift-multiplex recording and phase-code-multiplex recording are performed are deposited by sequentially repeating the steps

of:

forming the holographic recording layer on the substrate;

projecting the reference beam to which a phase code pattern different for each address is provided and the object beam onto the holographic recording layer to achieve shift-multiplex recording over an entire surface of the holographic recording layer;

forming the next holographic recording layer on the holographic recording layer; and

projecting the object beam having an incident angle modulated and the reference beam to which a phase code pattern different for each address is provided onto the next holographic recording layer to achieve shift-multiplex recording over an entire surface of the next holographic recording layer.